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AUTHOR Hayes, David A.
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ABSTRACT

A substantial amount of literature in education and psychology supports the notion that reading combined with writing enhances comprehension and recall. To investigate how various writing tasks affect thinking, a pilot study was conducted, which produced results consistent with the hypothesis that text engagement (student interaction with written material) would occur to the extent that various writing tasks required reorganizing the language of the text. In a study undertaken to reproduce these results with a larger group, 176 high school students were assigned to four groups--three were given writing tasks (formulating questions, comparing and contrasting, and paraphrasing) to follow their reading and one was given a nonwriting task (a matching exercise). Students' written recall of the assigned reading was analyzed to compare the extent to which the inference operations--generalization, integration, deletion, and construction--were instigated by the various reading/study tasks. The results indicated that the students who formulated questions and wrote compare-contrast statements generated more information than those who paraphrased and performed the matching exercise; and that the students who formulated questions produced more constructions than any group and restated relatively more top level information. These results indicate that writing tasks requiring reorganization of texts (formulating questions and comparing-contrasting) tend to engage more of the students' own intellectual resources in the study of those texts. (References, tables of results, and appendixes--the target text, test booklets, scoring sheet, and examples of student recalls--are included.) (LLZ)

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Directing Thinking Through Writing in Response to Reading

David A. Hayes
Department of Reading Education
309 Aderhold Building
University of Georgia

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National Reading Conference
San Diego, California
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ABSTRACT

Numerous assertions have been made that thinking can be guided and knowledge developed in study activity which combines reading and writing tasks. To test the plausibility of such assertions a pilot study and an experiment investigated inference operations associated with three different writing tasks and worksheet exercises assigned as study activities to accompany reading. High school boys and girls read a sequence of related science passages and reacted to each by paraphrasing, formulating questions, comparing and contrasting or completing matching exercises on worksheets. A comparison of information given in retelling a pretreatment target text indicated that quality of inferences differed across writing tasks. Writing questions and compare-contrast statements resulted in the generation of significantly more new information ($p < .025$), and writing questions resulted in the recall of proportionally more superordinate information ($p < .05$). The results are explained as stemming from the organizing requirements of writing.

Directing Thinkng Through Writing

in Responses to Reading

With increasing attention being given to the context of language behavior, renewed attention is being paid to a view of reading that takes account of the circumstance of reading and its effect upon the way a reader takes information from a text and applies it to meet the purposes of reading (e.g., Rosenblatt, 1969; Iser, 1972; Spiro, 1980). Such a view of reading invites speculation about how teachers may influence comprehension by the contingencies they establish in assigning study tasks attendant to reading. Along this line of speculation, a growing body of literature in education and psychology advocates combining writing with reading as a profitable study technique. Page (1974), Kintsch and van Dijk (1978), Flower (1979), Beach and Bridwell (1984), and others argue that when combined with reading, writing fosters the identification of significant information in a text and encourages reflection on that information as it is organized into a coherent written response. Wittrock (1983) asserts that writing generates relations among the parts of a text and between a text and its reader's experience. Eanet and Manzo (1976) and Odell (1980) further claim that by varying the writing task in response to reading, a teacher can exercise control over the way students think about the content of a text.

Empirical support for these arguments remains fairly sparse, although some evidence for the instructional value of coupling writing with reading has been reported in recent years. Dansereau and colleagues (1974) found that college students who paraphrased in writing or described orally a prose passage performed better on a delayed recall test than students who merely read the

passage, but not better than students who generated questions about the passage. Bretzing and Kulhavy (1979) report an experiment in which the students who took notes in paraphrase form were better able to recall information from a text than students who took verbatim notes or than students who took no notes. Doctorow, Wittrock, and Marks (1978) report that students who were given paragraph headings and wrote a one sentence summary upon reading each paragraph of a story performed better on comprehension and memory tests than students who wrote a summary but were not given paragraph headings and students who did not respond to the text in writing. Taylor and Berkowitz (1980) offer strong support for writing as an aid to comprehension with a study finding that students who wrote a one sentence summary of a textbook passage remembered more of the passage and performed better on a comprehension posttest than other students who either used a study guide or answered questions. Newell, (1984) concludes from a comparison of taking notes, answering questions, and writing essays that essay writing best helps high school students integrate the material they read. Taylor and Beach (1984) report finding that skill in remembering a text is related to organizational skill in writing and that both of these skills can be improved through instruction in expository text organization. On the basis of an experiment comparing a direct versus an indirect approach to instruction in composing paragraph summaries, Hare and Borchardt (1984) claim no effective difference between direct and indirect instruction, though they did find that students receiving instruction outperformed control students on measures of efficiency and application of rules for writing summaries. Bean and Steenwyk (1985) also report an experiment comparing direct versus indirect instruction in summary writing, demonstrating on both a measure of summary writing quality and a standardized

test of reading comprehension that sixth-grade students who recieved explicit step-by-step instruction outperformed students who received instruction based on finding main ideas of paragraphs.

Evidence has yet to be produced that can support Odell's (1980) or Eanet and Manzo's (1976) notion that variant writing tasks differentially influence learning from text. Eanet (1978) does report that she successfully taught students to write certain types of annotations for prose materials but that on measures of recall and comprehension writing the annotations did not differentiate students from other students who did not write annotations. A common purpose implicit in these investigations is the validation of conventional classroom practices which involve brief writing tasks. Although the results are somewhat mixed, taken together they do suggest that writing in response to reading might positively affect students' thinking and learning. In particular the work of Bretzing and Kulhavy (1979), Doctorow, et al. (1978), Newell (1984), and Taylor and Beach (1984) suggests effects associated with the organizing requirements of writing tasks. Still needed is research in this vein to explain how writing tasks can be employed to guide students' thinking about the material they are assigned to read. If writing tasks are rationally to be assigned in combination with reading to direct students' thinking about the material they are assigned to study, more needs to be known about how variant writing tasks affect thinking itself.

It was toward addressing this need that the present research sought to find out how certain readily assignable writing tasks, when combined with reading, might influence the quality of inferences students make in response to a text they have read. Writing collected from high school students was examined for evidence of inference making operations associated with different

writing tasks assigned as study activities to accompany reading. Inference making was examined within the scope of van Dijk's (1977) scheme of representing meaning. In this scheme, meaning is represented through a summarizing process which reduces discourse to its constituent propositions and organizes them to fit with one's existing state of knowledge. Four distinct inference operations are implicated: (1) generalization (by which the information of two or more propositions is combined into a single, inclusive proposition), (2) integration (by which top level information of discourse suffices to represent subordinate information), (3) deletion (by which extraneous and nonessential information is eliminated), and (4) construction (by which is added a new proposition which can substitute for propositions of the discourse at a more global level).

According to van Dijk's theory of discourse processing, any activity which induces greater engagement with discourse will result in producing more inferential information in recalling that discourse. Thus it was expected that written responses to texts would yield evidence of inferential processing to the extent that they induce engagement with the text. The present research investigated the differential effectiveness of three writing tasks and a non-writing study task for constructively engaging students with texts. The writing tasks resembled the kind of writing researchers (Applebee, 1981; Donlon, 1980) observe to be most prevalent in high school content area classes, i.e., brief responses to instructions to provide information about subject area concepts, often given on study sheets. The writing tasks were paraphrasing, comparing-contrasting, and formulating questions. The nonwriting study tasks were paper and pencil matching exercises. The general hypothesis was that

text-engagement would be observed to the extent that these study tasks required reorganizing the language of study material.

It was hypothesized that the writing activities would give evidence of greater engagement with the reading materials than would the matching activities. Among the writing activities, it was expected that comparing-contrasting and formulating questions would yield evidence of greater engagement with the material read than would paraphrasing. Whereas paraphrasing is a straightforward text restatement that usually follows the same organization as the text itself, comparing and contrasting involve an active search for parallels between texts, and formulating questions involves language transformations that cast the content in language structures different from the original text. Comparing-contrasting and formulating questions would be expected to focus and intensify attention differently than would paraphrasing or matching items on a pencil and paper exercise. These hypotheses were tested initially in a preliminary study which provided an appraisal of their tenabilitiy and then in a controlled experiment which could yield reliable results.

Pilot Study

Detecting evidence of inference operations as suggested by van Dijk requires analyzing language produced in the recollection of a text. Because typically few statements are generated in the recall of a text, and because among them wide variation in quality can be expected, no attempt was made in the pilot study to calculate the rareness of sampling error in obtaining measures of inference making. Instead, a modest number of students were involved in a data collection procedure designed to assess the prospect of

experimentally detecting differences in inference production across variant study tasks.

Forty high school students recalled in writing a text on the general topic of machines both before and after responding to a series of related texts in one of three different writing modes (paraphrasing, comparing-contrasting, and formulating questions) or in a nonwriting control condition which students performed paper and pencil matching exercises. With an approach suggested by van Dijk (1977), students' writing was inspected for evidence of inference making operations. The inspection took account of the extent to which the students had merely reproduced the text, deleted noncontributing statements, combined text information into generalized statements, let subordinate information be integrated into superordinate statements, and added new information constructed in recall.

The groups were equated by covarying on their initial written recall and compared on the quality of inferences produced in their final recall. This comparison indicated that inference operations associated with the writing tasks generally differed from those associated with the matching tasks and that quality of inferences differed across writing tasks. As shown in Table 1, all of the writing groups generated substantially more constructions than the nonwriting control group. Among the writing groups, the students assigned to write questions and compare-contrast statements generated more constructions than the students assigned to paraphrase.

Insert Table 1 About Here

The findings of the pilot study were consistent with the research hypotheses. Indeed, the data on construction were quite encouraging,

attributing as they did 6% of the variance to treatment for a medium effect size. Apparently cognitive events could be instigated by the study tasks differentially according to the degree of text reorganization they entailed. Due to the small number of students participating in this exploratory effort, however, statistical power could not be achieved sufficient to rule out the possible effects of sampling error in obtaining the results. Thus a decision was made to proceed with a controlled experiment that could yield a more reliable outcome.

Experiment

The experiment was designed to determine the effects that writing in response to reading might have upon the way students produce inferences about a topic they are studying. The aim was to find out whether writing in response to reading would affect inference production differently than would doing study activity that does not involve writing and, if it did, whether variant modes of written response would affect differentially the quality of those inferences. On the basis of the findings of the preliminary study it was expected that writing tasks would produce significantly more evidence of text engagement than would the nonwriting study tasks; among the writing tasks, comparing-contrasting and formulating questions were expected to produce significantly more evidence of text engagement than would paraphrasing.

Design and Subjects

One hundred seventy-six tenth grade students from a comprehensive high school in rural northeast Georgia were assigned at random to one of four groups (n = 44 each) for comparison in a true experimental design, which was a

one-factor correlated-groups design. One group was a control group. For all participants pretreatment and posttreatment measures were correlated in order to equalize individual differences on these measures. Students who might have difficulty reading and responding to the texts were left out of the sample. Teacher judgment and standardized reading test scores were the criteria for screening students. Students scoring below the fourth stanine on the reading subtests of the Comprehensive Test of Basic Skills and other students whom teachers identified as slow readers were left out of the sample.

Materials

In order to observe the effects of the study tasks assigned under conditions comparable for all, the tasks were simultaneously assigned to students by means of booklets constructed so as to provide for the different responses to reading. The booklets contained prose passages constructed to facilitate detecting inferences as van Dijk (1977) supposes they are produced in remembering discourse. The focal passage of the experiment was a 325-word passage on machines. It was elaborated by four additional 150-word passages on each of the simple machines, the lever, the inclined plane, the pulley, and the wheel-and -axle. These passages are shown in the appendix.

The passage on machines, the focal passage of the experiment, was written to provide for detecting two of the four inference operations investigated by the study, deletion and integration. By their respective definitions, the inference operations of deletion and integration can only occur in response to particular textual contingencies. Evidence of deletion is given when readers' recall omits information that does not fit with or contribute to the discourse. Evidence of integration is given when readers' recall only indirectly represents information by its superordinate, subsuming proposition. Thus the

focal passage was written to contain seven noncontributory propositions to assess the extent to which the treatments were associated with their omission from recall. In the exhibit passage these propositions are enclosed in parentheses. The focal passage was also written so that propositions which were components or conditions of superordinate propositions were clearly linked to their superordinate proposition. This provided for assessing the extent to which the treatment conditions were associated with students' excluding propositions when their respective superordinate propositions were given in recall. Superordinate propositions are indicated by bold print in the exhibit passage. The four treatment passages on simple machines were adapted so that they were comparable in organization and readability. Each passage was introduced by a set of directions for responding after reading. All of these materials were assembled into booklets in four combinations, each corresponding to one of the four treatment conditions.

Procedure

The experiment was designed to provide comparison of inference producing qualities of four text study activities, three of which were brief writing tasks--paraphrasing, comparing-contrasting, formulating questions; the fourth activity involved matching exercises.

The students were given booklets according to their respective treatment group assignments and told that there would be phases of the activity when their classmates would be doing different tasks: while some students would be reading, others would be writing, and still others would be doing matching exercises. The students were told that they would be given oral instructions only about when to begin and when to go on to succeeding phases of the

activity but that for each phase they were to read and follow the directions printed in their booklets. A pattern of treatment activity followed in which students read and responded to the 150-word passage according to their respective treatment conditions four times in succession. The pattern of treatment activity is depicted in Figure 1.

Insert Figure 1 About Here

First, all students silently read the 325-word passage on machines. Following their reading, students were told to turn the page and without looking back write down as much as they could remember of the passage. This initial writing sample provided the covariate for removing from the analysis of students' post-treatment writing products their individual differences in discourse production. The students were not told that they would be asked to recall again the passage on Machines after performing the experimental study tasks.

As soon as all of the students ceased writing they were told to turn to the next page of their booklet and follow the directions written at the top of the page. At this point, all students were still doing the same activity, here to carefully read the passage on the lever. Then the students were told to turn the page over and follow the directions on the top of the page. The PARAPHRASE group were directed to summarize in their own words the lever passage, the QUESTION group to write down as many questions as they could make up for the passage, and the other two groups were directed to read and study a passage on the inclined plane.

Next, the PARAPHRASE and QUESTION groups followed written directions to read the passage on the inclined plane while the COMPARE-CONTRAST group followed directions to write down likenesses between levers and inclined planes, and the control group followed directions to match the lever and the inclined plane to a list of their characteristics. Then, while the PARAPHRASE group paraphrased the passage on inclined planes and the QUESTION group wrote questions for it, the COMPARE-CONTRAST group wrote down differences between levers and inclined planes. The control group did another matching exercise identifying examples of a list of implements as either levers or inclined planes. Since these tasks were intended to simulate the kinds of activities that teachers might assign as study activities, the directions instructed the students to refer to the passages as they completed the tasks.

This cycle of treatment activity was repeated for the passages on the pulley and the wheel-and-axle. When the students completed the activity associated with the latter two passages, they had responded to the texts according to their respective treatments assignments four times in succession.

The students were then instructed to turn to the last page of their booklet and follow the directions printed there: to write down as much as they could remember about the initial passage on machines without looking back.

Dependent Measures

Each student's pretreatment and posttreatment recalls were inspected for evidence that could link the writing/study tasks to differences between the initial and final recollections of the 325-word passage on Machines. The aim here was to compare the extent to which basic operations of inference

making were instigated by the reading/study tasks assigned. Among a number of techniques for investigating readers' inference operations, the approach described by van Dijk (1977) best served this purpose. Straightforward and relatively simple to apply, it provided for identifying discrete categories of inference. Because there is little likelihood of overlap in the occurrence of these operations as they are explained by van Dijk, they can be identified with a high degree of accuracy. The following account of the scoring procedures describes how students' initial and final written recalls were compared to the Machines passage. Depicted in the appendix is an actual protocol with scoring sheet completed.

Pretreatment and posttreatment recalls were scored by comparing them against a template of the Machine passage's text base. The template was prepared after the example of van Dijk (1977) by dividing the Machines passage into its constituent propositions and displaying them according to their level or ordination and relatedness. Propositions were clausal segments. There were 24 distinct propositions of which seven were extraneous propositions that were listed separately. In other words, the Machines passage's seventeen internally relevant propositions were organized into an outline and its seven irrelevant propositions were listed separately. This template is exhibited in the appendix. Against the template each recall was compared for content that either matched or gave evidence of the inference-making operations described by van Dijk.

Each instance of a match between propositions of a recall and the propositions of the Machines passage was counted as a text reproduction. The content of the recall and the template text base did not have to match verbatim to be counted a text reproduction since, according to van Dijk,

neither text comprehension nor text recall is exact. As an example, a text reproduction was counted for this near match between the proposition of the template and the proposition rendered in a student's recall:

[All machines can be classified as simple or complex machines.]	=>	"All machines are either simple or complex."

A generalization was counted for each proposition of a student's recall that was entailed by two or more propositions of the Machines passage such that the student's proposition could substitute for the template propositions that entailed it. In other words, each instance of a student's combining two or more of the passage's propositions into a more inclusive proposition was counted as a generalization. For example:

[Machines reduce the effort required to do a job by providing mechanical advantage.] [Mechanical advantage is gained by changing the speed, direction, or amount of a force.]	=>	"Machines make a job easier by changing amount, speed, direction of the force."

A deletion was counted for each one of the passage's seven extraneous propositions omitted from the student's recall. Absence of their mention, either explicitly as a text reproduction or implicitly as an entailment of a generalization, was considered an instance of a deletion. As an example of the scoring procedure, if a student's recall contained one of the seven extraneous propositions as a text reproduction and one as an entailment of a generalization, by subtraction five instances of deletion were noted.

Each instance of omitting from recall a proposition whose information was expressed by a more global proposition was counted as an integration. Said another way, if a proposition was included in the recall, every omission of its elaborative, subordinate propositions was noted as an integration. For example:

[All machines can be classified as simple or complex machines.] [Some complex machines contain thousand of parts.] [Complex machines are made up of combinations of simple machines.]	=> "All machines are either simple or complex."

Since two elaborative propositions were omitted from restatement with the more global proposition, two instances of integration were counted. Had the recall included one of the elaborative propositions, say, that "There are thousands of parts in some machines," then only one integration was counted.

The introduction of new information into a student's recall was identified as a construction. Constructions were propositions of a student's recall that were new in the sense of not being part of the text base nor being generalized combinations of specific propositions of the Machines passage. In order words, constructions were newly added propositions which could not be linked to any particular proposition of the Machines passage. For example, even though the passage gave no more information about the inclined plane than to say that it spreads out resistance to effort, if a student wrote, "The longer and narrower an inclined plane, the less effort required," a construction was noted.

Analysis

Using these measures, one of the participating teachers and the investigator independently scored the pretreatment and posttreatment recollections of the Machines passage. To enhance the reliability of the scoring procedure, notation of each discourse operation was justified by indicating how the operation conformed to its definition in the study. Our percentage of agreement was high, and with brief discussion we resolved our few disagreements. Before discussion agreement reached 93% on the identification of text reproductions, 99% on the identification of generalizations, 92% on the identification of integrations, 94% on the identification of deletion, and 96% on the identification of constructions.

Students' written summaries of the Machines passage were examined for qualities that might be distinctly linked to mode of study assigned for the four content-related passages. To adjust for wide variation in individual students' discourse production that would mask differences due to treatment, each outcome measure was correlated with its incidence in the initial summarizing exercise by covariance analysis procedure. To aid interpreting the magnitude of treatment effect on each outcome variable, eta squared values were computed. When the ANCOVA found treatment effects to be statistically significant, differences in the groups' mean performance were compared against the standard error of difference among those means, whose value was the criterion for a determination of statistically significant difference.

Results

The analysis of students' pre- and post-experimental recollections of the Machines passage revealed that the assigned study tasks had differentially influenced inference production as van Dijk suppose that it occurs. Table 2 summarizes both unadjusted and adjusted performance of the treatment groups on each outcome variable. The results were in the direction predicted, though support only hypotheses about differences among the writing tasks themselves.

The results show that the treatment groups were undifferentiated in the amount of text reproduction given in recall, $F < 1$, N.S. Writing activity was not shown to be associated with the number of propositions of the Machines passage restated in students' written recollection of that passage. Practice in writing out responses to the texts did not result in any greater writing fluency than completing matching exercises.

On the two dependent variables related to text reproduction, deletion and generalization, the treatment groups were also undifferentiated, $F < 1$, N.S., on both measures. Across all groups most of the extraneous propositions were left out of students' recalls, six out of seven on average. This finding supports that aspect of van Dijk's theory which holds that propositions which do not contribute to the coherence or meaning of discourse tend not to be remembered. Few generalizations were produced by students in any treatment condition. Where original text propositions were remembered, students tended to restate them without combining their elements into more abstract forms.

Analysis of the integration data revealed a medium effect due to treatment $\eta^2 = .048$, $F(3, 171) = 2.85$, $p < .05$. Students' performance in the question writing group ($\bar{X}$ adj. = 4.676) differed significantly from that of students in

the compare-contrast writing group ($\bar{X}$ adj. = 3.628), $p < .01$, and the matching group ($\bar{X}$ adj. = 3.889), $p < .05$. The results indicate that students in the question writing condition let top level discourse structures subsume their subordinate structures. Another way of reporting this finding is that significantly more of the information remembered by students in that group was superordinate information.

Analysis of the construction data showed a medium effect size due to treatment, $\eta^2 = .059$, F (3, 171) = 3.61, $p < .025$, distinguishing the recalls of students in the compare-contrast and question writing groups. Students in these two groups generated more new information ($\bar{X}$ adj. = 2.1475) than the students in the matching and paraphrasing groups ($\bar{X}$ adj. = 1.378), $p < .05$. The number of constructions produced by students in the question writing group alone ($\bar{X}$ adj. = 2.496) significantly exceeded the number produced by students in every other group, the compare-contrast writing group ($\bar{X}$ adj. = 1.799), $p < .05$, the paraphrase writing group ($\bar{X}$ adj. = 1.185), $p < .01$, and the matching group ($\bar{X}$ = 1.571), $p < .01$. The performance of the compare-contrast writing group significantly differed only from that of the paraphrasing group, $p < .05$.

Discussion

Combining reading and writing tasks ranks high among study activities advocated for productively engaging students with texts. The kind of writing likely to be assigned in actual classroom practice is that of jotting down brief answers to study questions and of recording information in completion exercises. To test the potential of directing reading with this kind of writing assignment, basic inference operations were investigated as they might vary across brief writing tasks. An attempt was made to find out how students

might differentially orient their basic operations of thinking about a topic across variant modes of written responses to reading.

The results of the experiment do not support the hypothesis that written responses to texts induce greater engagement with the general topic of those texts than do responses made through paper and pencil matching exercises. However, the results do support the hypothesis that the way writing is combined with reading differentially impacts a person's comprehending a topic under study. The results show that writing in response to reading can affect students' thinking about what they read. More exactly, the results show that form of written response to reading influences inference making operations as they were operationally defined in this study. All of the groups were comparable in amount of original text reproduced in recall. Yet among the writing groups, the students who formulated questions restated relatively more top level information and generated more constructions in recall than did students who performed the other study tasks. Interpreted in light of van Dijk's scheme of making inferences, the incidence of construction relative to text reproduction in retelling a text provides an index of global, integrative thinking about the discourse topic.

Kintsch and van Dijk (1978) explain that the extent to which discourse is integrated into a person's ideational system can be gauged by the proportion of global propositions in a person's retelling. Here the finding of more constructions and integrations in students' retelling after completing a series of brief writing tasks suggests that the act of writing itself can bring into play the students' own resources for knowing about the topic. The disproportionately high occurrence of construction and integration in the

retellings of the QUESTION group suggests how writing may activate learners' own knowledge, at both the sentence level and the discourse level.

As with all writing acts, writing questions involves deliberation on syntax choices that have semantic effects, but the syntax choices of question-writing include choices required to complete passive transformations. Fillmore (1968) and Kurylowicz (1964) explain that passive transformations are grammatical processes which mediate semantic relations. Changing verb forms from active to passive, and vice versa, redefines case relations and rearranges case networks which give form to procedures of thought and representations of discourse content. Actively transforming the syntactic structures of a text concomitantly affects the semantic representations which those structures serve to organize. The results of the present study indicate that where representations of the texts operated upon are embedded in the representations of another text, the latter representations are also affected. This was most evidenced in the recollections of the focal passage by students whose treatment tasks were to reshape the language of the related texts into questions. Because the syntax operations of the question-writing task differed radically from those of the other writing tasks, the findings provide evidence that forming and transforming syntax during writing influence the way inferences are made about a topic of study.

Beyond the level of syntax formation, organizing what one reads through writing may have further effects on the way that inferences are made. A number of writers (Bracewell, 1983; Bracewell, Frederiksen & Frederiksen, 1982; Tierney & Pearson, 1983) suggest that sequentially organizing conceptual content in both reading and writing creates a propositional representation and a scheme for staging it. The operations of framing and staging are alike in

both reading and writing, except that they become more automatic in reading due to greater experience in reading. When a person must consciously organize language structures to form a conceptual frame, the regulatory operations of processing discourse are not as easily accessed. The results of the present experiment indicate that insofar as these operations involve construction of more global inferences they may be rendered more accessible through certain kinds of writing tasks than through others. Hardly do the results show that writing improves reading comprehension. Nor do they show that formulating questions about a text results in greater learning of its content than do paraphrasing or comparing and contrasting. However, they do indicate that brief writing tasks which involve reorganization of texts tend to engage more of the students' own intellectual resources in the study of those texts. Thus the results lend plausibility to claims by Odell (1980) and by Eanet and Manzo (1976) that the way students think about a topic under study can be influenced by the kind of writing tasks they are assigned to do in response to reading.

Because writing as performed in this experiment is obviously not the only way of encoding responses to a text, one might reasonably wonder whether the present results would have been any different had the students responded to the texts in some other way. Research on the inferential operations involved in making responses to a text in ways other than these writing tasks stands to clarify the value of various linguistic forms of response for learning from texts. If, for example, the result of the present experiment were replicated with oral responses, previous explanations of observed differences between speaking and writing (Chafe, 1980; Harrell, 1957; O'Donnell, 1974) would bear qualification, as Kroll (1977) and Loban (1976) suggest, according to the context in which they occur. Such a replication would indicate extending

research on inferences associated with limited responses to probes made during interactive discussion about a text. Investigation on directing interactive discussion to elicit thinking strategies like the ones elicited by the tasks of the present study holds promise for explaining in inferential terms the transactions of directed reading procedures.

Whether students can be induced to adopt deliberate strategies of framing and regulating their own mental activities in processing discourse during study has yet to be objectively demonstrated. Obviously, taking control of tacit mental activities to develop them into strategies that can be deliberately applied during study becomes critical if a person is skillfully to combine reading and writing as a way of learning. Toward achieving this end, promising are instructional activities that foster the development of organizing skills. Previous investigators (Bretzing and Kulhavy, 1979; Doctorow, et al., 1978; Newell, 1984; Taylor and Beach, 1984) report research which suggests that successful reading-study activities achieve positive results largely because they enhance the ability to organize. The findings of the present investigation point to an apparent organizing effect induced by some kinds of writing activity. With further investigation we may learn how combining reading and writing can capitalize upon this organizing effect to promote deliberate strategy application during study.

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Figure 1

Pattern of Experimental Activity

All Students Read -> All Students Recall -> Students Follow Respective -> All Students Recall
Machines Passage Machines Passage Treatment Sequences Machines Passage

Treatments

PARAPHRASE	Read -> Lever	Write -> Para-phrase	Read -> IncPl	Write -> Para-phrase	Read -> WhlAxl	Write -> Para-phrase	Read -> Pulley	Write Para-phrase
QUESTION	Read -> Lever	Write -> Ques-tions	Read -> IncPl	Write -> Ques-tions	Read -> WhlAxl	Write -> Ques-tions	Read -> Pulley	Write Ques-tions
COMPARE/ CONTRAST	Read -> Lever	Read -> IncPl	Write -> Compar-isons	Write -> Con-trasts	Read -> WhlAxl	Read -> Pulley	Write -> Compar-isons	Write Con-trasts
MATCH	Read -> Lever	Read -> IncPl	Match ->	Match ->	Read -> WhlAxl	Read -> Pulley	Match ->	Match

N = 44 each treatment

Table 1

Pilot Study Results: Adjusted Mean Number of Discourse Operations Reflected in Recall of Passage on Machines

Operation	Study Task			
	Writing Questions	Writing Compare-Contrast Statements	Writing Para-phrases	Matching Exercises
Text Reproduction	3.97	4.41	5.05	4.57
Deletion	6.18	5.90	5.36	5.95
Generalization	1.42	1.14	1.23	1.42
Integration	3.13	2.77	2.95	3.24
Co..struction	2.74	2.18	1.60	.87

Table 2

Mean Number of Discourse Operations Reflected in Recall of Passage on Machines

Operation	Study Task		
	Writing Questions	Writing Compare-Contrast Statements	Writing Para-phrases
Text Reproduction			
Pre-treatment	4.591 (2.394)	5.045 (2.667)	4.841 (2.486)
Post-treatment	3.386 (2.264)	4.114 (2.911)	3.954 (3.169)
Adjusted	3.642	3.991	4.001
Deletion			
Pre-treatment	6.318 (.857)	5.886 (1.185)	5.977 (1.171)
Post-treatment	6.363 (1.221)	5.932 (1.605)	5.931 (1.860)
Adjusted	6.275	6.007	5.972
Generalization			
Pre-treatment	.455 (.663)	.523 (.743)	.273 (.585)
Post-treatment	.227 (.475)	.318 (.561)	.295 (.631)
Adjusted	.212	.277	.349
Integration			
Pre-treatment	4.341 (2.614)	4.545 (2.872)	3.273 (2.356)
Post-treatment	4.863 (3.224)	3.931 (2.518)	3.705 (3.167)
Adjusted	4.676	3.628	4.123
Construction			
Pre-treatment	1.159 (1.171)	1.000 (1.078)	1.386 (1.367)
Post-treatment	2.522 (2.556)	1.681 (1.393)	1.727 (1.452)
Adjusted	2.496	1.799	1.185

n = 44 each treatment

Standard deviations are in parentheses

APPENDIX

Displaying Materials of the Investigation

Target Text with Superordinate and Irrelevant Propositions Indicated

Template of the Target Text

Scoring Sheet

Example of Student Recalls

Example of Scoring Student Recalls

Booklets Used by Each Treatment Group

MACHINES

Machines have great practical value because they make work faster and easier. A bicycle can move you from place to place in less time than you can walk. (In many parts of the world, the bicycle is the main form of transportation.) A sewing machine allows you to sew much faster than sewing by hand. (Tailors routinely use sewing machines.) If you've ever mixed a cake by hand, you know that it is easier to beat the batter with an electric mixer. (Modern bakeries use electric mixers.) Elevators are machines that can lift many people through a great distance. (Most tall buildings are equipped with elevators.)

Machines enable us to do more work with less effort. (They leave us more time for leisure.) Machines reduce the effort required to do a job by providing mechanical advantage. They provide mechanical advantage by changing the speed, direction, or amount of resistance force. (Calculating mechanical advantage is a basic task of an engineer.)

All machines can be classified as simple or complex machines. (Modern man has produced a wide variety of machines.) Complex machines are made up of combinations of simple machines. Simple machines are devices which reduce work with one movement.

Four very useful simple machines are the lever, the pulley, the inclined plane, and the-wheel-and-axle. A lever reduces the effort needed to move an object by applying pressure against a fulcrum. A pulley can be used to move a heavy object upward by exerting a downward force. An inclined plane works by spreading out resistance to effort force. By turning a wheel, resistance against its axle is transferred to the wheel itself.

Template of the Target Text

Relevant Propositions

Machines have great practical value.

Machines make work faster and easier.

A bicycle can move you from place to place in less time than you can walk.

A sewing machine allows you to sew much faster than sewing by hand.

If you've ever mixed a cake by hand, you know that it is easier to beat the batter with an electric mixer.

Elevators are machines that can lift many people through a great distance.

Machines enable us to do more work with less effort.

Machines reduce the effort required to do a job by providing mechanical advantage.

They provide mechanical advantage by changing the speed, direction, or amount of resistance force.

All machines can be classified as simple or complex machines.

Complex machines are made up of combinations of simple machines.

Simple machines are devices which reduce work with one movement.

Four very useful simple machines are the lever, the pulley, the inclined plane and the wheel-and-axle.

A lever reduces the effort needed to move an object by applying pressure against a fulcrum.

A pulley can be used to move a heavy object upward by exerting a downward force.

An inclined plane works by spreading out resistance to effort force.

By turning a wheel, resistance against its axle is transferred to the wheel itself.

Irrelevant Propositions

In many parts of the world, the bicycle is the main form of transportation.

Tailors routinely use sewing machines.

Modern bakeries use electric mixers.

Most tall buildings are equipped with elevators.

They leave us more time for leisure.

Calculating mechanical advantage is a basic task for an engineer.

Modern man has produced a wide variety of machines.

Scoring Sheet

Initial Recall	Final Recall	
_____	_____	Text Reproduction
_____	_____	Verbatim
_____	_____	Paraphrase
_____	_____	Incomplete
_____	_____	Integration
_____	_____	To text reproduction
_____	_____	To generalization
_____	_____	Deletion
_____	_____	Generalization
_____	_____	Relevant/Relevant Propositions
_____	_____	Relevant/Irrelevant Propositions
_____	_____	Irrelevant/Irrelevant Propositions
_____	_____	Across Paragraphs
_____	_____	Contiguous Propositions
_____	_____	Erroneous
_____	_____	Construction
_____	_____	Imported from treatment texts
_____	_____	Plausible
_____	_____	Erroneous
_____	_____	Partial-Includes elements of text propositions

INITIAL RECALL

Without looking back, write down as much as you can remember of the passage on MACHINES.

Machines make work alot easier and faster. A machine can be complex or simple. A complex machine is made up of a lot of simple machines and a simple machine is just made up of one part. A machine can change the direction, speed, and the resistance force of an object. A bicycle is the main transportation in some places. A sewing machine can sew faster than the human hand. Machines help people do things [redacted] faster and get to places faster.

FINAL RECALL

Without looking back, write down as much as you can remember of the passage on MACHINES.

Machines make work easier and faster to do. There are many types of machines that make work easier for humans. A machine can be either complex or simple. A complex machine can be harder to work with, because of all of its parts. A simple machine is just what it says it is simple, because it isn't made up as many parts as the complex machine. Some examples of machines are a sewing machine, blender (electric), and a bicycle. [redacted]

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Scoring Sheet

Initial Recall	Final Recall	
6	2	Text Reproduction
5	2	Verbatim
1		Paraphrase
		Incomplete
4	3	Integration
4	3	To text reproduction
		To generalization
6	7	Deletion
0	1	Generalization
	1	Relevant/Relevant Propositions
		Relevant/Irrelevant Propositions
		Irrelevant/Irrelevant Propositions
		Across Paragraphs
	1	Contiguous Propositions
		Erroneous
2	4	Construction
		Imported from treatment texts
1	4	Plausible
1		Erroneous
1		Partial-Includes elements of text propositions

Constructions: Initial Recall

A simple machine is just made up of one part.
Machines help people...get to places faster.

Constructions: Final Recall

There are many types of machines that make work easier for humans.
A complex machine can be harder to work with because of all of its parts.
A simple machine is just what it says it is, simple.
Because it isn't made up of as many parts as the complex machine.

Experimental Materials Used by
Students Assigned to Write
Paraphrases

MACHINES

Machines have great practical value because they make work faster and easier. A bicycle can move you from place to place in less time than you can walk. In many parts of the world, the bicycle is the main form of transportation. A sewing machine allows you to sew much faster than sewing by hand. Tailors routinely use sewing machines. If you've ever mixed a cake by hand, you know that it is easier to beat the batter with an electric mixer. Modern bakeries use electric mixers. Elevators are machines that can lift many people through a great distance. Most tall buildings are equipped with elevators.

Machines enable us to do more work with less effort. They leave us more time for leisure. Machines reduce the effort required to do a job by providing mechanical advantage. They provide mechanical advantage by changing the speed, direction, or amount of resistance force. Calculating mechanical advantage is a basic task of an engineer.

All machines can be classified as simple or complex machines. Modern man has produced a wide variety of machines. Complex machines are made up of combinations of simple machines. Simple machines are devices which reduce work with one movement.

Four very useful simple machines are the lever, the pulley, the inclined plane, and the wheel-and-axle. A lever reduces the effort needed to move an object by applying pressure against a fulcrum. A pulley can be used to move a heavy object upward by exerting a downward force. An inclined plane works by spreading out resistance to effort force. By turning a wheel, resistance against its axle is transferred to the wheel itself.

Without looking back, write down as much as you can remember of the passage on MACHINES.

READ THIS PASSAGE CAREFULLY

THE LEVER

A lever is a simple machine consisting of a bar that is free to move about upon a point called a fulcrum. Examples of a lever include a bottle opener, claw hammer, and wrecking bar. The type and use of a lever varies according to the relative location of the effort force, resistance force, and fulcrum. With the most efficient lever, effort force is applied at one end of its bar to overcome resistance force at the other end. Two things affect the action of a lever, the amount of force at each end of the lever and the distance between the force and the fulcrum. Multiplied by each other, effort force and distance from the fulcrum constitute the moment of a lever. For instance, a man exerting 10 lb. of force on a lever 5 feet from its fulcrum creates a moment of 50 lb.

In your own words, write down as much as you can about the passage you just read on the LEVER. It is all right to look back at the passage.

READ THIS PASSAGE CAREFULLY

THE INCLINED PLANE

An inclined plane is a slanted surface used for raising objects to higher elevations or for cutting. Inclined planes that raise things include stairs, mountain roads, escalators, and ramps. Less effort force is needed to raise objects with inclined planes because the objects are moved along a slanted surface. When the same objects are lifted straight up, a larger effort force is applied through a short distance. The mechanical advantage of an inclined plane is calculated by dividing its length by its height. For example, a ramp three feet in length and one foot in height has a mechanical advantage of 3. Wedges, knives, lawn mower blades, and can opener blades are inclined planes whose mechanical advantage is determined similarly by dividing their length by their thickness. The longer and narrower these implements, the less effort force required to overcome resistance force.

In your own words, write down as much as you can about the passage you just read on the INCLINED PLANE. It is all right to look back at the passage.

READ THIS PASSAGE CAREFULLY

THE PULLEY

A pulley is a simple machine that changes the amount, speed, and direction of a force. A kind of rotating lever, a pulley is a wheel that turns on an axle. A pulley can be either fixed or movable, and it can be used either by itself or in combination with other pulleys.

A single pulley which is fixed in position changes the direction of resistance force but does not multiply effort force. The effort force equals the resistance force. It has a mechanical advantage of 1.

Movable pulleys offer a mechanical advantage equal to the number of support ropes. A single pulley which moves has two support ropes, one fixed and one that moves up and down with the weight. Thus it has a mechanical advantage of 2. A combination of three pulleys which change the direction of a force three times has three support ropes. It offers a mechanical advantage of 3.

In your own words, write down as much as you can about the passage you just read on the PULLEY. It is all right to look back at the passage.

READ THIS PASSAGE CAREFULLY

THE WHEEL-AND-AXLE

The wheel-and-axle is a simple machine that operates on the same principle as the lever and pulley. The direction of force is changed, and force is reduced by spreading it over a greater distance. The force applied to the wheel is applied to the axle, but the wheel turns through a larger distance than the axle. So the force on the wheel moves through a greater distance than the force on the axle. The difference gives the wheel-and-axle its mechanical advantage.

The mechanical advantage for a wheel-and-axle is calculated by dividing the diameter of the wheel by the diameter of the axle. For example, to calculate the mechanical advantage of a steering wheel whose wheel is 15 inches across and whose steering rod is one inch across, you divide 15 by 1. The mechanical advantage is 15.

In your own words, write down as much as you can about the passage you just read on the WHEEL AND AXLE. It is all right to look back at the passage.

Without looking back, write down as much as you can remember of the passage on MACHINES.

Experimental Materials Used by
Students Assigned to Write
Questions

MACHINES

Machines have great practical value because they make work faster and easier. A bicycle can move you from place to place in less time than you can walk. In many parts of the world, the bicycle is the main form of transportation. A sewing machine allows you to sew much faster than sewing by hand. Tailors routinely use sewing machines. If you've ever mixed a cake by hand, you know that it is easier to beat the batter with an electric mixer. Modern bakeries use electric mixers. Elevators are machines that can lift many people through a great distance. Most tall buildings are equipped with elevators.

Machines enable us to do more work with less effort. They leave us more time for leisure. Machines reduce the effort required to do a job by providing mechanical advantage. They provide mechanical advantage by changing the speed, direction, or amount of resistance force. Calculating mechanical advantage is a basic task of an engineer.

All machines can be classified as simple or complex machines. Modern man has produced a wide variety of machines. Complex machines are made up of combinations of simple machines. Simple machines are devices which reduce work with one movement.

Four very useful simple machines are the lever, the pulley, the inclined plane, and the wheel-and-axle. A lever reduces the effort needed to move an object by applying pressure against a fulcrum. A pulley can be used to move a heavy object upward by exerting a downward force. An inclined plane works by spreading out resistance to effort force. By turning a wheel, resistance against its axle is transferred to the wheel itself.

Without looking back, write down as much as you can remember of the passage on MACHINES.

READ THIS PASSAGE CAREFULLY

THE LEVER

A lever is a simple machine consisting of a bar that is free to move about upon a point called a fulcrum. Examples of a lever include a bottle opener, claw hammer, and wrecking bar. The type and use of a lever varies according to the relative location of the effort force, resistance force, and fulcrum. With the most efficient lever, effort force is applied at one end of its bar to overcome resistance force at the other end. Two things affect the action of a lever, the amount of force at each end of the lever and the distance between the force and the fulcrum. Multiplied by each other, effort force and distance from the fulcrum constitute the moment of a lever. For instance, a man exerting 10 lb. of force on a lever 5 feet from its fulcrum creates a moment of 50 lb.

Use this page to write down as many questions as you can make up about the LEVER as a simple machine. You don't need to answer your own questions — just write them down. It is all right to look back at the passage.

READ THIS PASSAGE CAREFULLY

THE INCLINED PLANE

An inclined plane is a slanted surface used for raising objects to higher elevations or for cutting. Inclined planes that raise things include stairs, mountain roads, escalators, and ramps. Less effort force is needed to raise objects with inclined planes because the objects are moved along a slanted surface. When the same objects are lifted straight up, a larger effort force is applied through a short distance. The mechanical advantage of an inclined plane is calculated by dividing its length by its height. For example, a ramp three feet in length and one foot in height has a mechanical advantage of 3. Wedges, knives, lawn mower blades, and can opener blades are inclined planes whose mechanical advantage is determined similarly by dividing their length by their thickness. The longer and narrower these implements, the less effort force required to overcome resistance force.

Use this page to write down as many questions as you can make up about the INCLINED PLANE as a simple machine. You don't need to answer your own questions — just write them down. It is all right to look back at the passage.

READ THIS PASSAGE CAREFULLY

THE PULLEY

A pulley is a simple machine that changes the amount, speed, and direction of a force. A kind of rotating lever, a pulley is a wheel that turns on an axle. A pulley can be either fixed or movable, and it can be used either by itself or in combination with other pulleys.

A single pulley which is fixed in position changes the direction of resistance force but does not multiply effort force. The effort force equals the resistance force. It has a mechanical advantage of 1.

Movable pulleys offer a mechanical advantage equal to the number of support ropes. A single pulley which moves has two support ropes, one fixed and one that moves up and down with the weight. Thus it has a mechanical advantage of 2. A combination of three pulleys which change the direction of a force three times has three support ropes. It offers a mechanical advantage of 3.

Use this page to write down as many questions as you can make up about the PULLEY as a simple machine. You don't need to answer your own questions — just write them down. It is all right to look back at the passage.

READ THIS PASSAGE CAREFULLY

THE WHEEL-AND-AXLE

The wheel-and-axle is a simple machine that operates on the same principle as the lever and pulley. The direction of force is changed, and force is reduced by spreading it over a greater distance. The force applied to the wheel is applied to the axle, but the wheel turns through a larger distance than the axle. So the force on the wheel moves through a greater distance than the force on the axle. The difference gives the wheel-and-axle its mechanical advantage.

The mechanical advantage for a wheel-and-axle is calculated by dividing the diameter of the wheel by the diameter of the axle. For example, to calculate the mechanical advantage of a steering wheel whose wheel is 15 inches across and whose steering rod is one inch across, you divide 15 by 1. The mechanical advantage is 15.

Use this page to write down as many questions as you can make up about the WHEEL AND AXLE as a simple machine. You don't need to answer your own questions — just write them down. It is all right to look back at the passage.

Without looking back, write down as much as you can remember of the passage on MACHINES.

Experimental Materials Used by
Students Assigned to Write
Compare and Contrast Statements

MACHINES

Machines have great practical value because they make work faster and easier. A bicycle can move you from place to place in less time than you can walk. In many parts of the world, the bicycle is the main form of transportation. A sewing machine allows you to sew much faster than sewing by hand. Tailors routinely use sewing machines. If you've ever mixed a cake by hand, you know that it is easier to beat the batter with an electric mixer. Modern bakeries use electric mixers. Elevators are machines that can lift many people through a great distance. Most tall buildings are equipped with elevators.

Machines enable us to do more work with less effort. They leave us more time for leisure. Machines reduce the effort required to do a job by providing mechanical advantage. They provide mechanical advantage by changing the speed, direction, or amount of resistance force. Calculating mechanical advantage is a basic task of an engineer.

All machines can be classified as simple or complex machines. Modern man has produced a wide variety of machines. Complex machines are made up of combinations of simple machines. Simple machines are devices which reduce work with one movement.

Four very useful simple machines are the lever, the pulley, the inclined plane, and the-wheel-and-axle. A lever reduces the effort needed to move an object by applying pressure against a fulcrum. A pulley can be used to move a heavy object upward by exerting a downward force. An inclined plane works by spreading out resistance to effort force. By turning a wheel, resistance against its axle is transferred to the wheel itself.

Without looking back, write down as much as you can remember of the passage on MACHINES.

THE LEVER

A lever is a simple machine consisting of a bar that is free to move about upon a point called a fulcrum. Examples of a lever include a bottle opener, claw hammer, and wrecking bar. The type and use of a lever varies according to the relative location of the effort force, resistance force, and fulcrum. With the most efficient lever, effort force is applied at one end of its bar to overcome resistance force at the other end. Two things affect the action of a lever, the amount of force at each end of the lever and the distance between the force and the fulcrum. Multiplied by each other, effort force and distance from the fulcrum constitute the moment of a lever. For instance, a man exerting 10 lb. of force on a lever 5 feet from its fulcrum creates a moment of 50 lb.

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An inclined plane is a slanted surface used for raising objects to higher elevations or for cutting. Inclined planes that raise things include stairs, mountain roads, escalators, and ramps. Less effort force is needed to raise objects with inclined planes because the objects are moved along a slanted surface. When the same objects are lifted straight up, a larger effort force is applied through a short distance. The mechanical advantage of an inclined plane is calculated by dividing its length by its height. For example, a ramp three feet in length and one foot in height has a mechanical advantage of 3. Wedges, knives, lawn mower blades, and can opener blades are inclined planes whose mechanical advantage is determined similarly by dividing their length by their thickness. The longer and narrower these implements, the less effort force required to overcome resistance force.

Write down as many ways as you can think of that LEVERS and INCLINED PLANES are alike. Consider things like how they are used, how they work, and examples of each. It is all right to look back at the passages.

Use this page to write down as many ways as you can think of that LEVERS and INCLINED PLANES are <u>different</u>. Again consider how they are used, how they work, and examples of each. It is all right to look back at the passages.

THE PULLEY

A pulley is a simple machine that changes the amount, speed, and direction of a force. A kind of rotating lever, a pulley is a wheel that turns on an axle. A pulley can be either fixed or movable, and it can be used either by itself or in combination with other pulleys.

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Write down as many ways as you can think of that PULLEYS and WHEEL-AND-AXLES are alike. Consider things like how they are used, how they work, and examples of each. It is all right to look back at the passages.

Use this page to write down as many ways as you can think of that PULLEYS and WHEEL AND AXLES are <u>different</u>. Again consider how they are used, how they work, and examples of each. It is all right to look back at the passages.

Without looking back, write down as much as you can remember of the passage on MACHINES.

Experimental Materials Used by
Students Assigned to Complete
Matching Exercises

MACHINES

Machines have great practical value because they make work faster and easier. A bicycle can move you from place to place in less time than you can walk. In many parts of the world, the bicycle is the main form of transportation. A sewing machine allows you to sew much faster than sewing by hand. Tailors routinely use sewing machines. If you've ever mixed a cake by hand, you know that it is easier to beat the batter with an electric mixer. Modern bakeries use electric mixers. Elevators are machines that can lift many people through a great distance. Most tall buildings are equipped with elevators.

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All machines can be classified as simple or complex machines. Modern man has produced a wide variety of machines. Complex machines are made up of combinations of simple machines. Simple machines are devices which reduce work with one movement.

Four very useful simple machines are the lever, the pulley, the inclined plane, and the-wheel-and-axle. A lever reduces the effort needed to move an object by applying pressure against a fulcrum. A pulley can be used to move a heavy object upward by exerting a downward force. An inclined plane works by spreading out resistance to effort force. By turning a wheel, resistance against its axle is transferred to the wheel itself.

Without looking back, write down as much as you can remember of the passage on MACHINES.

THE LEVER

A lever is a simple machine consisting of a bar that is free to move about upon a point called a fulcrum. Examples of a lever include a bottle opener, claw hammer, and wrecking bar. The type and use of a lever varies according to the relative location of the effort force, resistance force, and fulcrum. With the most efficient lever, effort force is applied at one end of its bar to overcome resistance force at the other end. Two things affect the action of a lever, the amount of force at each end of the lever and the distance between the force and the fulcrum. Multiplied by each other, effort force and distance from the fulcrum constitute the moment of a lever. For instance, a man exerting 10 lb. of force on a lever 5 feet from its fulcrum creates a moment of 50 lb.

THE INCLINED PLANE

An inclined plane is a slanted surface used for raising objects to higher elevations or for cutting. Inclined planes that raise things include stairs, mountain roads, escalators, and ramps. Less effort force is needed to raise objects with inclined planes because the objects are moved along a slanted surface. When the same objects are lifted straight up, a larger effort force is applied through a short distance. The mechanical advantage of an inclined plane is calculated by dividing its length by its height. For example, a ramp three feet in length and one foot in height has a mechanical advantage of 3. Wedges, knives, lawn mower blades, and can opener blades are inclined planes whose mechanical advantage is determined similarly by dividing their length by their thickness. The longer and narrower these implements, the less effort force required to overcome resistance force.

Listed below are some uses and descriptions of the LEVER and the INCLINED PLANE. To the right are two columns, one under the heading of the LEVER and one under the heading of the INCLINED PLANE. Mark an X in the column that fits each statement. For some uses and descriptions, both the LEVER and the INCLINED PLANE are correct.

	LEVER	INCLINED PLANE
Provides mechanical advantage		
Increases effort force		
Decreases resistance force		
Distributes resistance force over distance		
Changes the direction of resistance force		
Can be used to raise an object		
Can be used to lower an object		
Can be used to loosen an object from a fixed position		
Can be used to hold an object firmly in place		
Can be used to move weights		
Has a fulcrum		
Creates a movement		
Can be used for cutting		
Can be used for prying		
Has an edge thinner than the edge on its opposite side		

Listed below are some examples of the LEVER and the INCLINED PLANE. To the right are two columns, one headed LEVER and one headed INCLINED PLANE. Mark an X in the column that fits each machine. Depending on their use, some machines can be either LEVER or INCLINED PLANE.

	LEVER	INCLINED PLANE
See-Saw		
Stairs		
Shovel		
Spoon		
Ramp		
Screwdriver		
Wrecking bar		
Wedge		
Bottle opener		
Knife		
Claw hammer		
Can opener		
Chisel		
Pliers		
Scissors		
Handsaw		
Bridge		
Oar		
Bumper jack		
Fork		

THE PULLEY

A pulley is a simple machine that changes the amount, speed, and direction of a force. A kind of rotating lever, a pulley is a wheel that turns on an axle. A pulley can be either fixed or movable, and it can be used either by itself or in combination with other pulleys.

A single pulley which is fixed in position changes the direction of resistance force but does not multiply effort force. The effort force equals the resistance force. It has a mechanical advantage of 1.

Movable pulleys offer a mechanical advantage equal to the number of support ropes. A single pulley which moves has two support ropes, one fixed and one that moves up and down with the weight. Thus it has a mechanical advantage of 2. A combination of three pulleys which change the direction of a force three times has three support ropes. It offers a mechanical advantage of 3.

THE WHEEL-AND-AXLE

The wheel-and-axle is a simple machine that operates on the same principle as the lever and pulley. The direction of force is changed, and force is reduced by spreading it over a greater distance. The force applied to the wheel is applied to the axle, but the wheel turns through a larger distance than the axle. So the force on the wheel moves through a greater distance than the force on the axle. The difference gives the wheel-and-axle its mechanical advantage.

The mechanical advantage for a wheel-and-axle is calculated by dividing the diameter of the wheel by the diameter of the axle. For example, to calculate the mechanical advantage of a steering wheel whose wheel is 15 inches across and whose steering rod is one inch across, you divide 15 by 1. The mechanical advantage is 15.

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Listed below are some uses and descriptions of the PULLEY and the WHEEL-AND-AXLE. To the right are two columns, one under the heading of the PULLEY and one under the heading of the WHEEL-AND-AXLE. Mark an X in the column that fits each statement. For some uses and descriptions, both the PULLEY and the WHEEL-AND-AXLE are correct.

	PULLEY	WHEEL AND AXLE
Provides mechanical advantage		
Increases effort force		
Decreases resistance force		
Distributes resistance force over distance		
Changes the direction of resistance force		
Can be used to raise an object		
Can be used to lower an object		
Operates in a fixed position		
Operates in a movable position		
Mechanical Advantage determined by number of wheels		
Mechanical Advantage determined by diameter of wheel		
Has an axle		

Listed below are some examples of the PULLEY and the WHEEL AND AXLE. To the right are two columns, one headed PULLEY and one headed WHEEL AND AXLE. Mark an X in the column that fits each machine. Depending on their use, some machines can be either PULLEY or WHEEL AND AXLE.

	PULLEY	WHEEL AND AXLE
bicycle sprocket		
wheelchair		
block-and-tackle		
eggbeater		
doorknob		
elevator		
steering wheel		
windlass		
lifeboat hoist		
wench		
fishing reel		
dumbwaiter		
window crank		
gear		
traverse rod (for drapes)		
venetian blind		
halyard (for raising a sail)		
flagpole device		
engine fan		
forklift hoist		

Without looking back, write down as much as you can remember of the passage on MACHINES.